A. COSTINOT (MIT) AND I. WERNING (MIT)

ROBOTS, TRADE, & LUDDISM

MOTIVATION

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- **Technological Progress:** Efficiency (+) vs. Inequality (-)

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  1. When is technological progress welcome?

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  1. When is technological progress welcome?
  2. How should government policy respond?

BACKGROUND

- **First Best:** Second Welfare Theorem
  - Lump-sum transfers ⇒ Redistribution without distortions
- **Second Best:** Diamond and Mirrlees (1971)
  - Unconstrained linear taxation ⇒ Production efficiency
  - No trade taxes; no taxes on robots

THIS PAPER

- **More realistic, restricted set of tax instruments**
  - After tax wages not fully controlled
  - before tax wages affected by policy (Naito 1999)

- **General framework**
  - Common principles: robots & trade
  - Theory delivers relevant sufficient statistics

RESULTS

1. When is technological change welcome?

2. How should government policy respond?

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     t^* = function of observable elasticities and shares

   - More robots/more trade may lower optimal taxes

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     t = function of observable elasticities and shares*

     Key sufficient statistic = elasticity effect on relative wages
   - More robots/more trade may lower optimal taxes

RELATED LITERATURE

- **Optimal Taxation**
  - Diamond-Mirrlees, Dixit-Norman
  - Naito, Guesnerie, Spector, Jacobs
  - Mayer-Riezman, Feenstra-Lewis, Rodrik, Grossman-Helpman, Hosseini-Shourideh
- **Welfare impact of technological progress or openness:**
  - Efficiency: Solow, Hulten, Bhagwati, Baeqee-Farhi
  - Distribution: Itskhoki, Antras-deGortari-Itskhoki, Galle-RodriguezClare-Yi
- **Optimal tax on robots:** Guerreiro-Rebelo-Teles

ROADMAP

- General Framework
- When Is Technological Change Welcome?
- How Should Government Policy Respond?
- Application to Robots and Trade

GENERAL FRAMEWORK

HOUSEHOLDS

- Household skills $\theta \sim F(\theta)$
- Goods $i = 1, ..., N$
- Preferences

$$U = u(C, n)$$
$$C = v(\{c_i\})$$

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weak separability

TECHNOLOGY

- Old Technology

$$G(\{y_i\}, \{n(\theta)\}) \leq 0$$

- New Technology

$$G^*(\{y_i^*\}) \leq 0$$

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  - Robots Example:

$$G^*(y_f^*, y_m^*) = \phi y_f^* + y_m^*$$

FEASIBILITY

- For each good i

$$y_i + y_i^* = \int c_i(\theta) dF(\theta)$$

- Note
  - allows general input-output between G and G^*
  - allows intermediate goods that are not consumed

TAXATION

- Household budget

$$\sum p_i c_i = w(\theta)n(\theta) - T(w(\theta)n(\theta))$$

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Labor Income Taxation

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- Firms profits
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$$\sum p_i^* y_i^*$$

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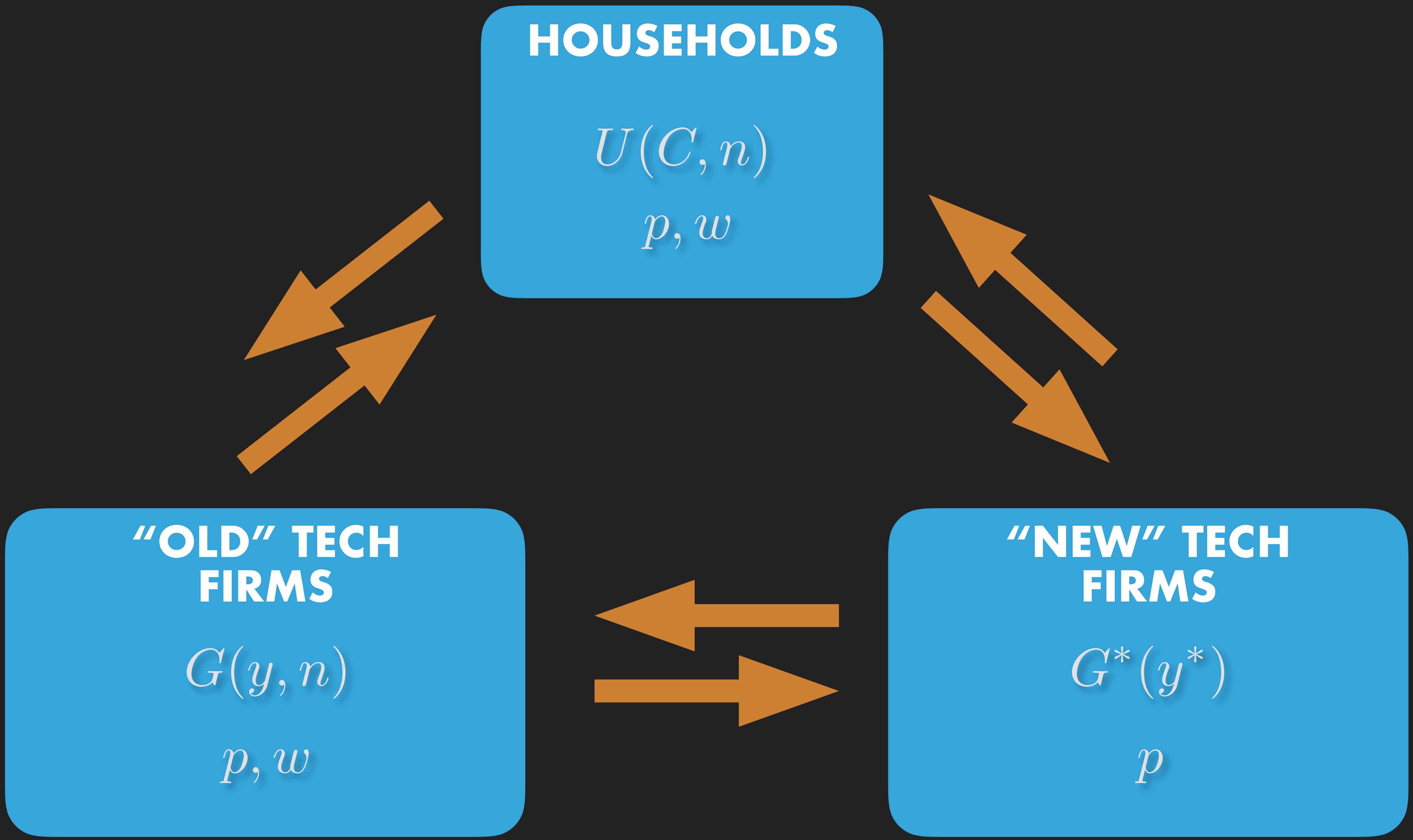
  - New Technology

$$\sum p_i^* y_i^*$$

- Taxes t^*:

$$p_i = (1 + t_i^*)p_i^*$$


HOUSEHOLDS
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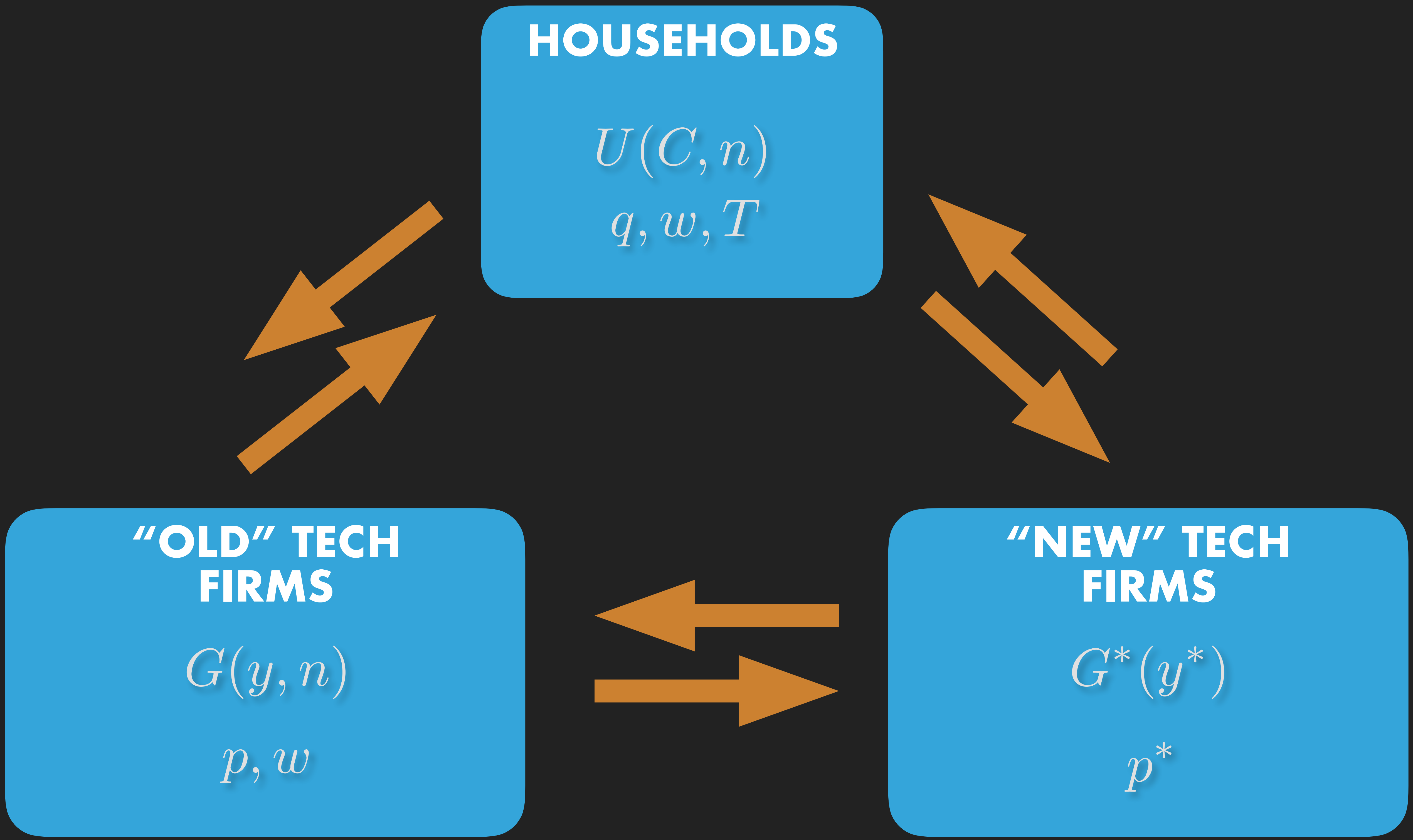
p, w
"OLD" TECH FIRMS
$G(y, n)$
p, w
"NEW" TECH FIRMS
$G^*(y^*)$
p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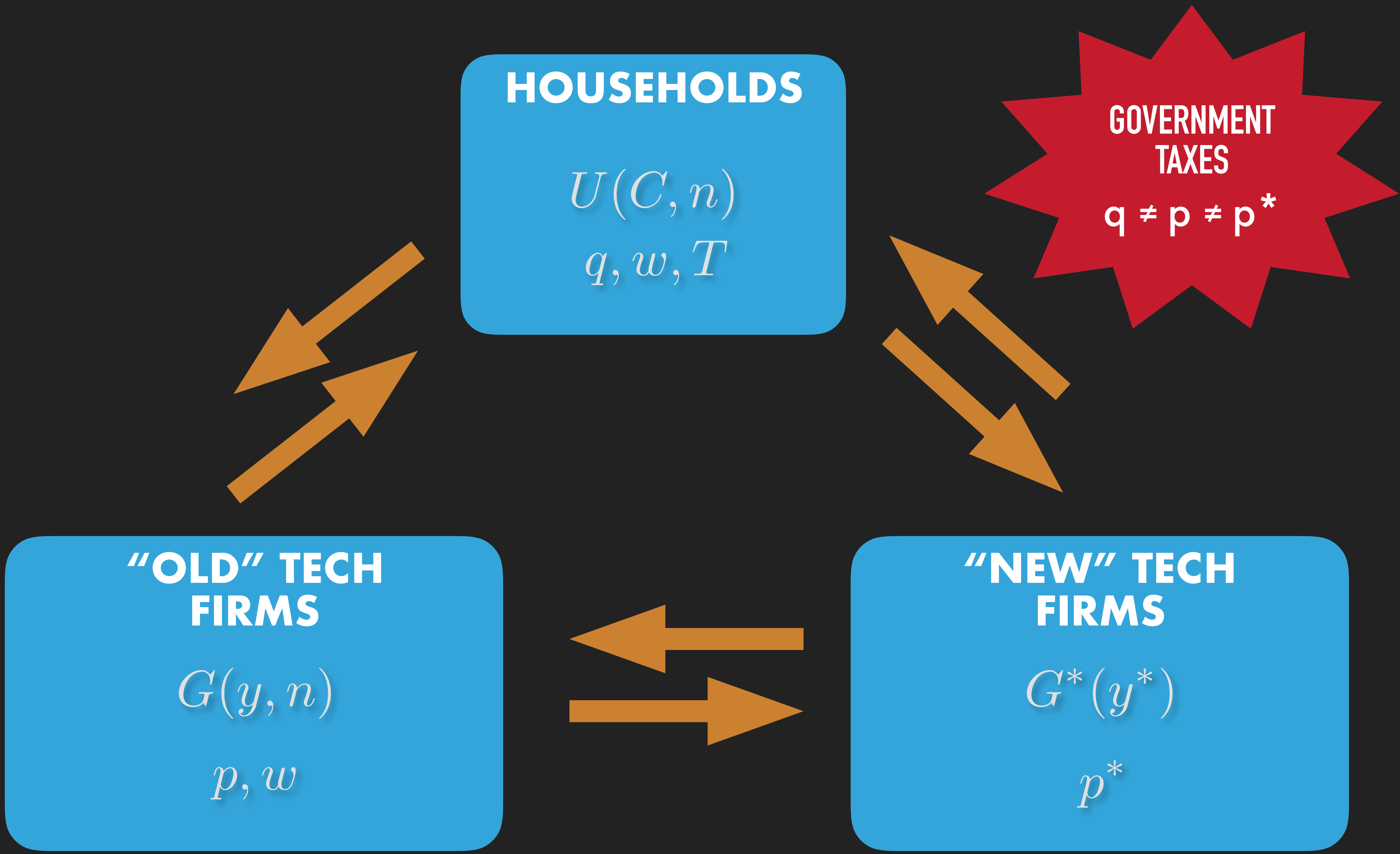
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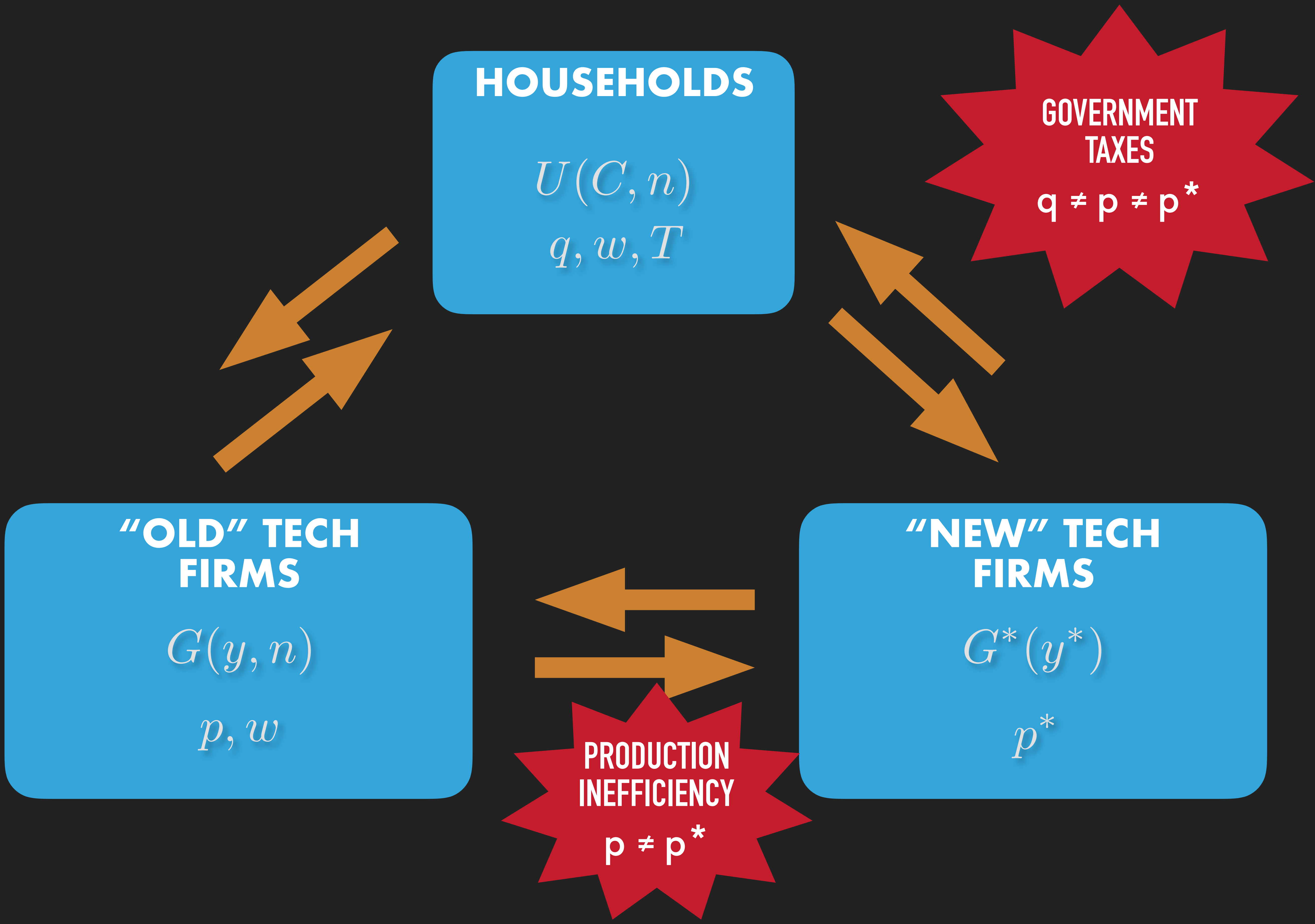
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PRODUCTION INEFFICIENCY
$p \neq p^*$

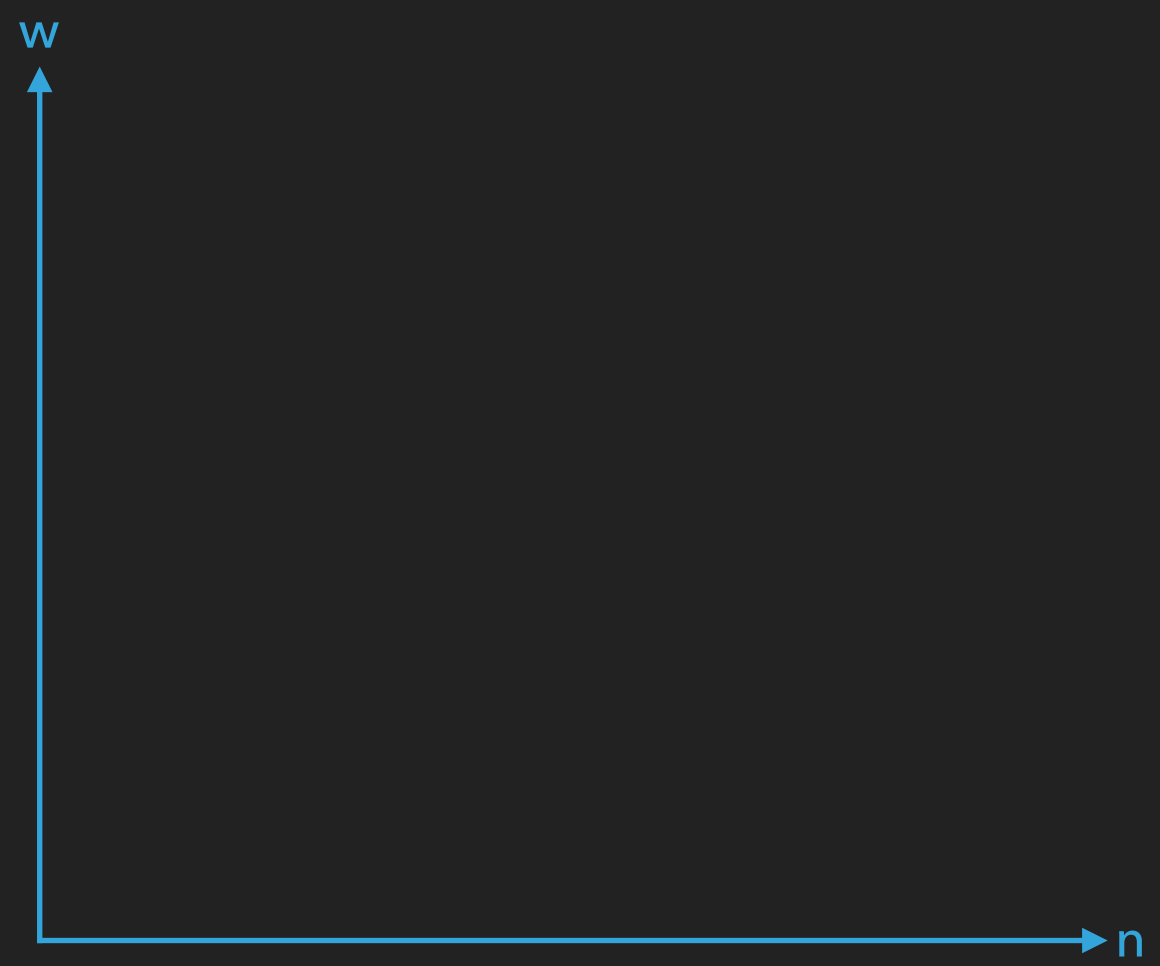
EQUILIBRIUM WAGES

- Crucial point…
  - Labor demand

    $$n^D(\{w(\theta)\}, \{p_i\}, \theta)$$

  - Equilibrium wages…

    $$w(\{p_i\}, \{n(\theta)\}, \theta)$$



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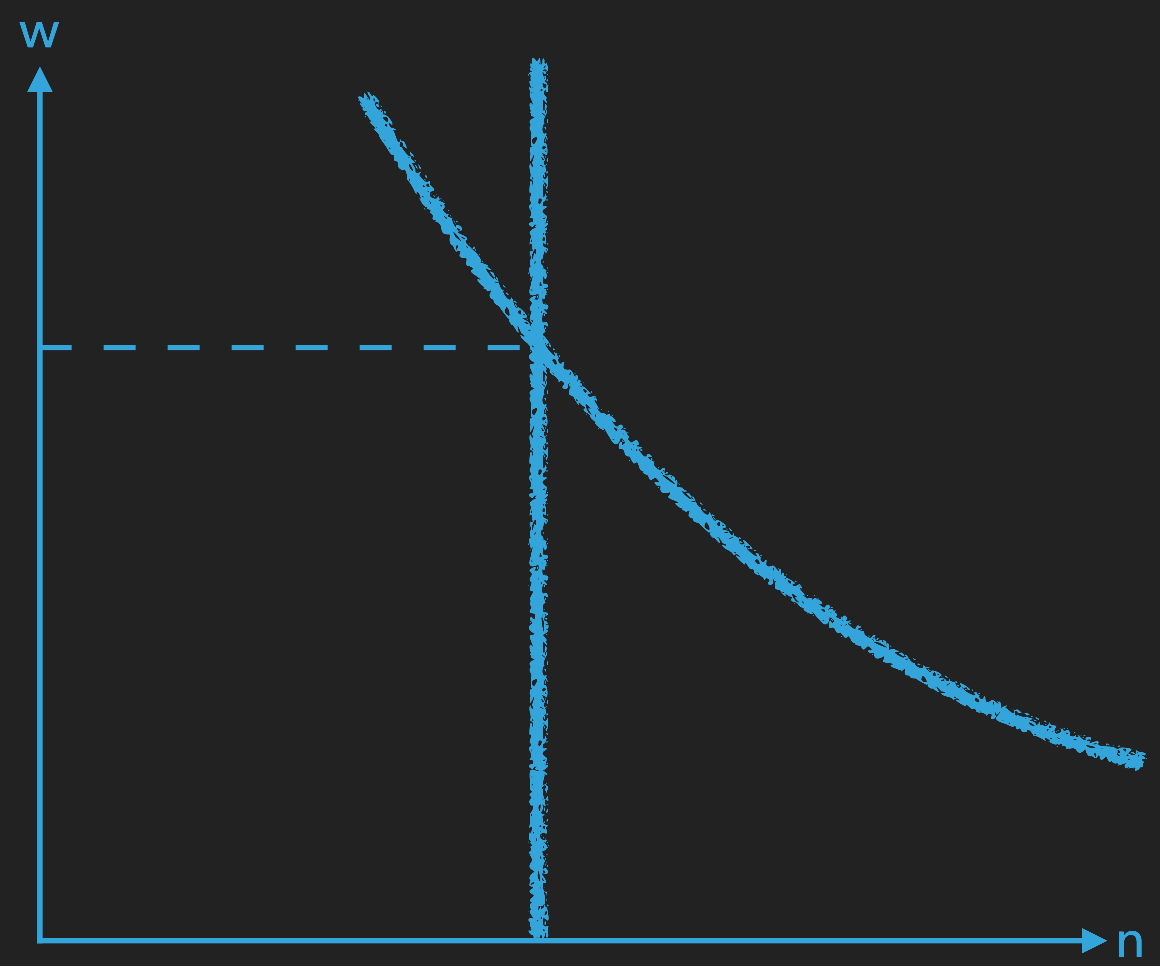

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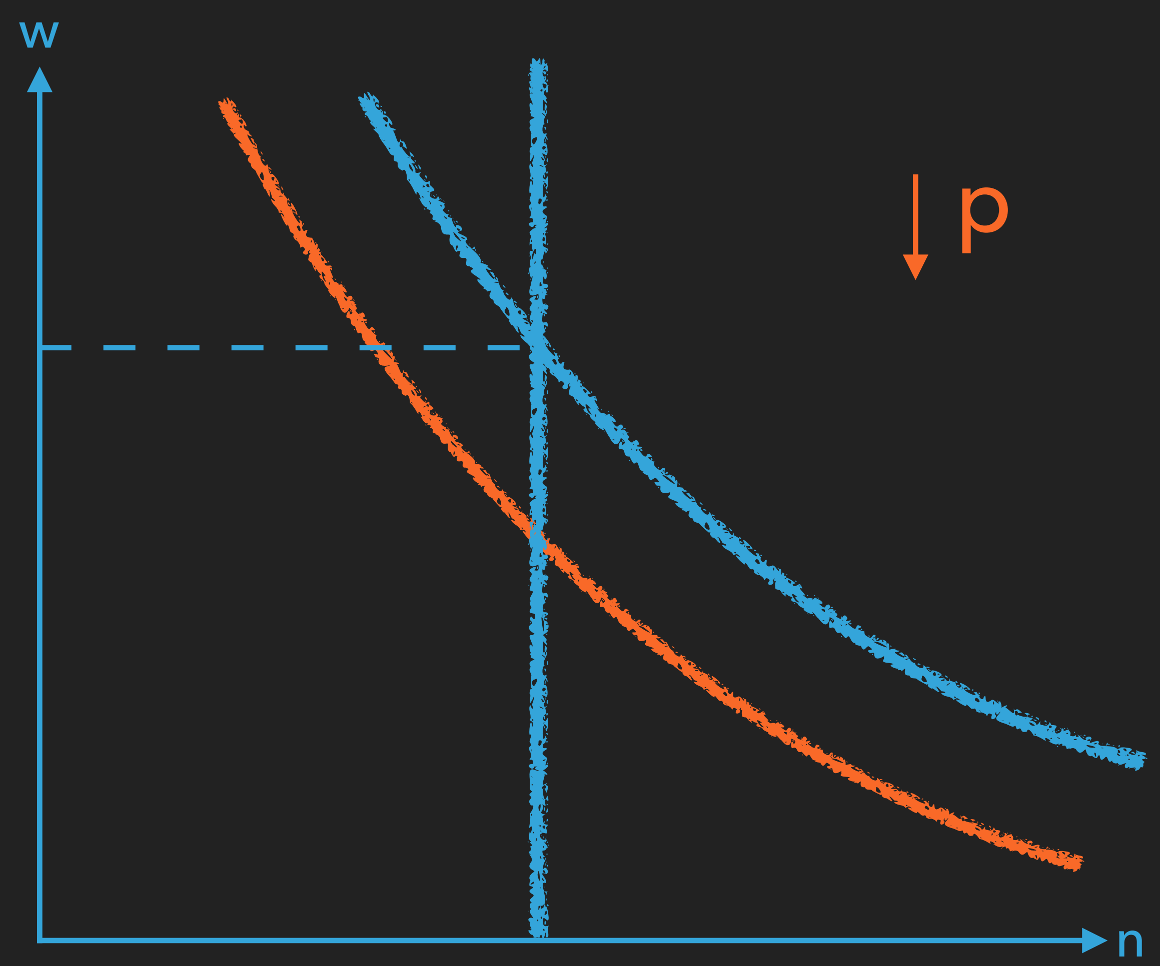

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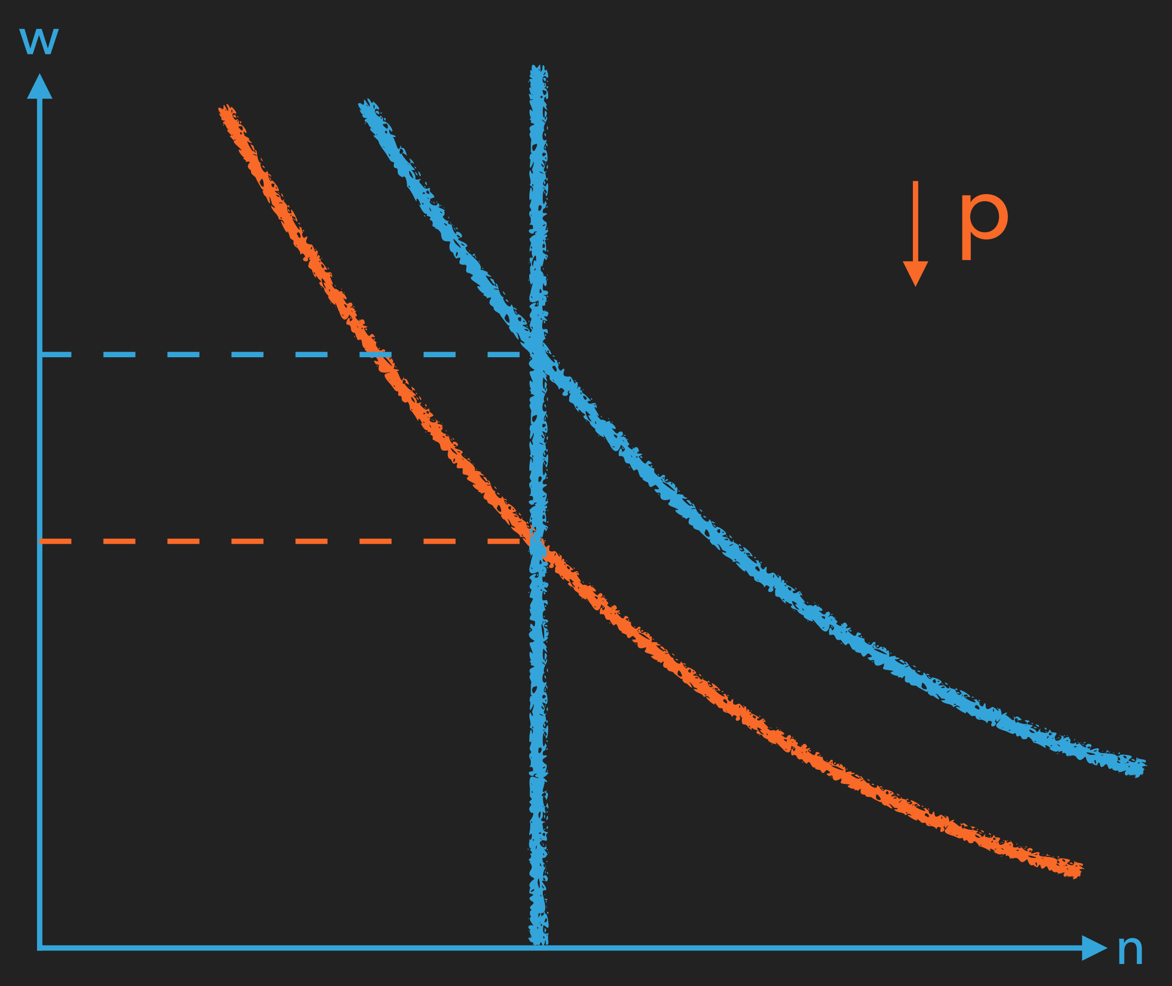

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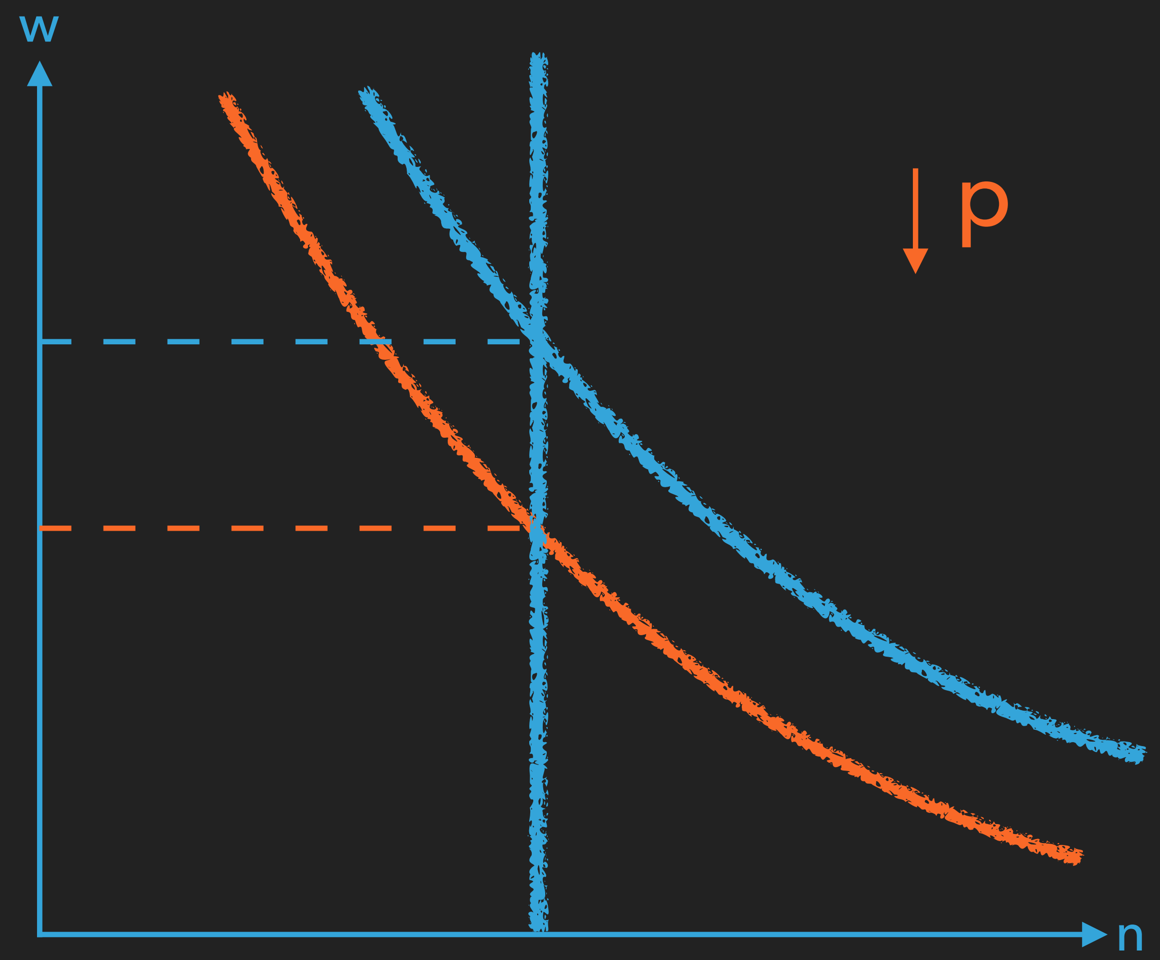

- t^* can be used to control before tax wages through p

GOVERNMENT

- Welfare Objective

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- Planning Problem: best competitive equilibrium with taxes

WHEN IS TECHNOLOGICAL CHANGE WELCOME?

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Same as first-best (Solow, Hulten)

No Immiserizing Growth!

PROP 1.

$$dW/d\phi \geq 0 \quad \Longleftrightarrow \quad \partial G^*/\partial\phi \leq 0$$

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- Envelope…

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PROP 1.

$$dW/d\phi \geq 0 \iff \partial G^*/\partial \phi \leq 0$$

- Extension: even if not optimal …

… Pareto improvement exists (extension of Dixit-Norman)

IMPLICATION: IMPACT OF TRADE SHOCK ONLY DEPENDS ON TOT

- Trade shock

$$\frac{dW}{d\phi} \geq 0 \Longleftrightarrow \sum \frac{d\bar{p}_i(\phi)}{d\phi} y_i^* \leq 0$$

- China Shock good or bad depends on TOT effect alone
- Gain from Trade = Integral below import demand!
- TOT externality = only rationale behind trade agreement (Bagwell-Staiger)
  - Envelope result robust to imperfect competition, domestic externalities, labor market imperfections

IMPLICATION: NO TAXATION OF INNOVATION

- Suppose new tech firms may also choose technology:

$$\{y_i^*, \phi^*\} \in \arg \max_{\{\tilde{y}_i\}, \phi \in \bar{\Phi}} \{\sum p_i^* \tilde{y}_i | G^*(\{\tilde{y}_i\}; \phi) \leq 0\}$$

- Government can restrict innovation: $\bar{\Phi} \subset \Phi$
- Envelope result ⇒ optimal technology satisfies:

$$\frac{\partial G^*(\{y_i^*\}; \phi^*)}{\partial \phi} = 0$$

- FOC of unconstrained firm ⇒ No restriction on innovation

HOW SHOULD GOVERNMENT POLICY RESPOND?

2ND WELFARE THEOREM

- **Lump-sum taxes**

$$T(w(\theta)n(\theta);\theta) = T(\theta)$$

- **At the Optimum**
  - Zero taxes on new technology $p = p^*$
  - Production efficiency: Free trade, no robot tax

DIAMOND-MIRRLEES (1971), DIXIT-NORMAN (1985)

- **Linear taxation**

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Why?

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→ **Key: complete tax system controls after-tax wages**

$$(1 - \tau(\theta))w(\theta)$$

THIS PAPER: MORE RESTRICTED TAX INSTRUMENTS

- **Non-linear income taxation**

$$T(w(\theta)n(\theta);\theta) = T(w(\theta)n(\theta))$$

incomplete labor tax

- **Endogenous wages…**

$$w(\{p_i\},\{n(\theta)\},\theta)$$

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  - first-order conditions
  - variations (Today)

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- Three formulas…
  - No change in T
  - No change in U
  - No change in n

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \to \delta p, \delta w, \delta y^*, \delta n$

$$(p - p^*) \cdot \delta y^* - \int \tau(z) w(z) \delta n(z)\, dz$$

$$= \int (\tilde{\lambda}(z) - 1)((1 - \tau(z)) n(z)\, \delta w(z) - c(z) \cdot \delta p - \delta T(w(z) n(z)))\, dz$$

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$$t_i^* = \frac{1}{p^*} \int \Big((\tilde{\lambda}(z) - 1)(1 - \tau(z)) + \tau(z)\, \varepsilon^u(z) \Big)\, n(z)\, \frac{dw(z)}{dy_i^*}|_{\delta T = 0}\, dz$$

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FORMULA #2

No Change in n …

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$\omega(z) = w'(z)/w(z)$

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welfare weight

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  - wage
  - ~~price/inflation~~
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WHY??????

No change in welfare!

detects Pareto improvements

SUMMARY

PROP 2.

$$t_i^* = \begin{cases} \frac{1}{p_i^*} \int \left((\tilde{\lambda}(z) - 1)(1 - \tau(z)) + \tau(z)\, \varepsilon^u(z) \right) n(z)\, \frac{dw(z)}{dy_i^*}|_{\delta T=0}\, dz - \int (\tilde{\lambda}(z) - 1) c(z) \cdot \frac{dp}{dy}|_{\delta T=0}\, dz \\ \frac{1}{p_i^*} \int \psi(z)(1 - \tau(z)) w(z) n(z)\, \frac{d\omega(z)}{dy_i^*}|_{\delta n=0}\, dz \\ \frac{1}{p_i^*} \int \tau(\theta) w(z) n(z)\, \frac{\epsilon(z)}{\epsilon(z)+1}\, \frac{1}{\omega(z)}\, \frac{d\omega(z)}{dy_i^*}|_{\delta U=0}\, dz \end{cases}$$

- All formulas…
  - Impact on wage sufficient statistic
  - Pigouvian intuition
  - At optimum: all formulas equivalent
  - Away from optimum: each formula identifies possible improvement

APPLICATION TO ROBOTS AND TRADE

PUTTING THE FORMULA TO WORK

- **Compute taxes using formula…**
  - Use reduced-form evidence as input
  - No further structure
- **Comparative static on technology change…**
  - How do taxes vary as machines/trade get cheaper?
  - More structure

WAGE EFFECTS: TRADE

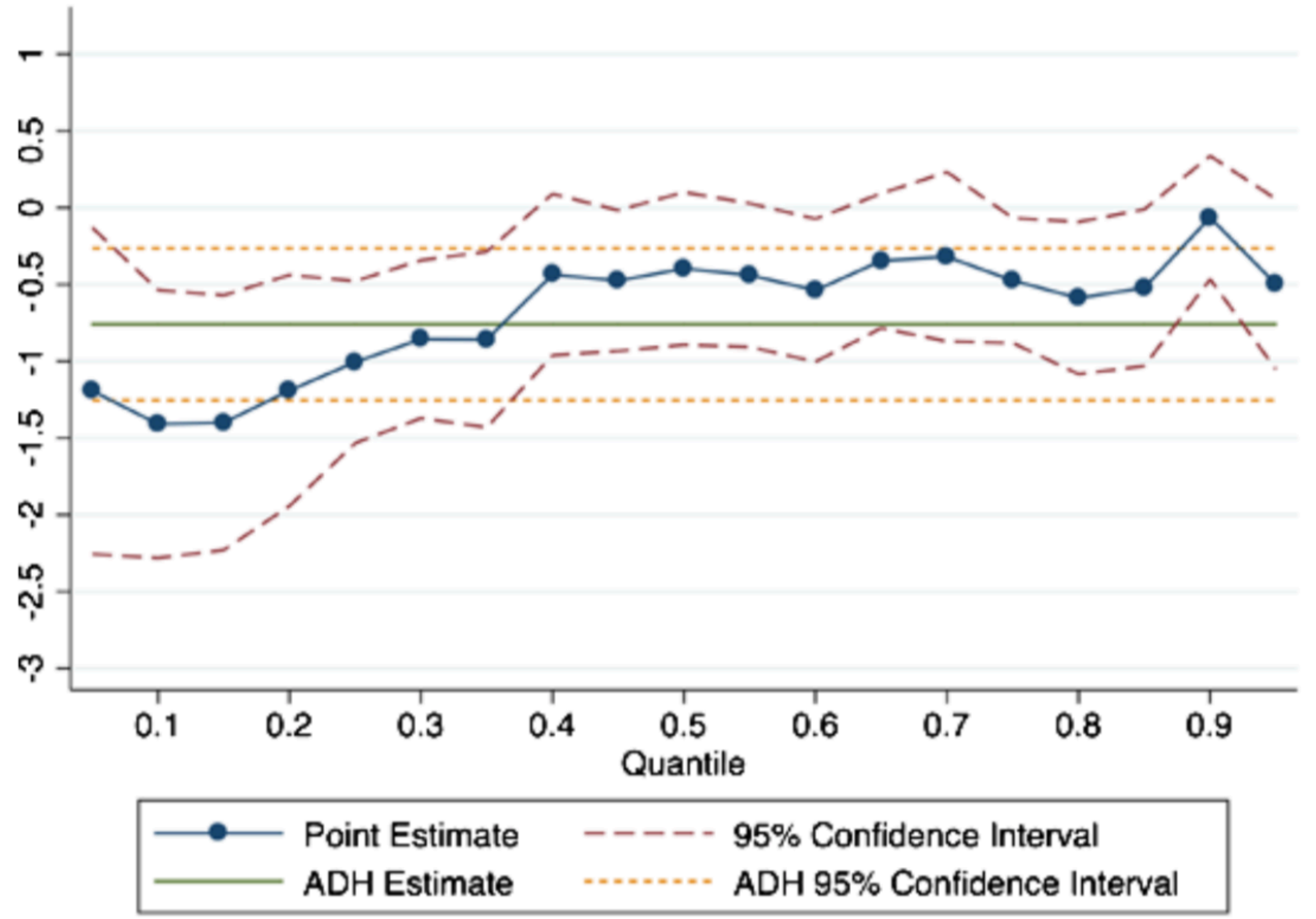

FIGURE 1.—Effect of Chinese import competition on conditional wage distribution: full sample. *Notes*: Figure plots grouped IV quantile regression estimates of the effect of a $1,000 increase in Chinese imports per worker on the conditional wage distribution (β_1 in equation (9) in the text when the change in average log wages for the commuting zone and decade corresponding to group g, $\Delta\overline{\ln w_g}$, is replaced with the change in the u-quantile of log wages $\Delta \ln w_g^u$). The dashed horizontal line is the ADH estimate of β_1 in equation (9). 95% pointwise confidence intervals are constructed from robust standard errors clustered by state and observations are weighted by CZ population, as in ADH. Units on the vertical axis are log points.

Chetverikov, Larsen, and Palmer (2016)

PARETO EFFICIENT TAX ON TRADE

Chetverikov-Larsen-Palmer

~0.5

$$t_m^* = \bar{\tau} \frac{\int w(z)n(z)dz}{p_m^* y_m} \frac{\epsilon}{\epsilon + 1} \frac{y_m}{\omega} \frac{d\omega}{dy_m}$$

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- Implication for Trade: $t_m^* \simeq 15\%$

with $\epsilon = 0.1$ and $\bar{\tau} = 0.1$ (Guner-Kaygusuz-Ventura)

WAGE EFFECTS: ROBOTS

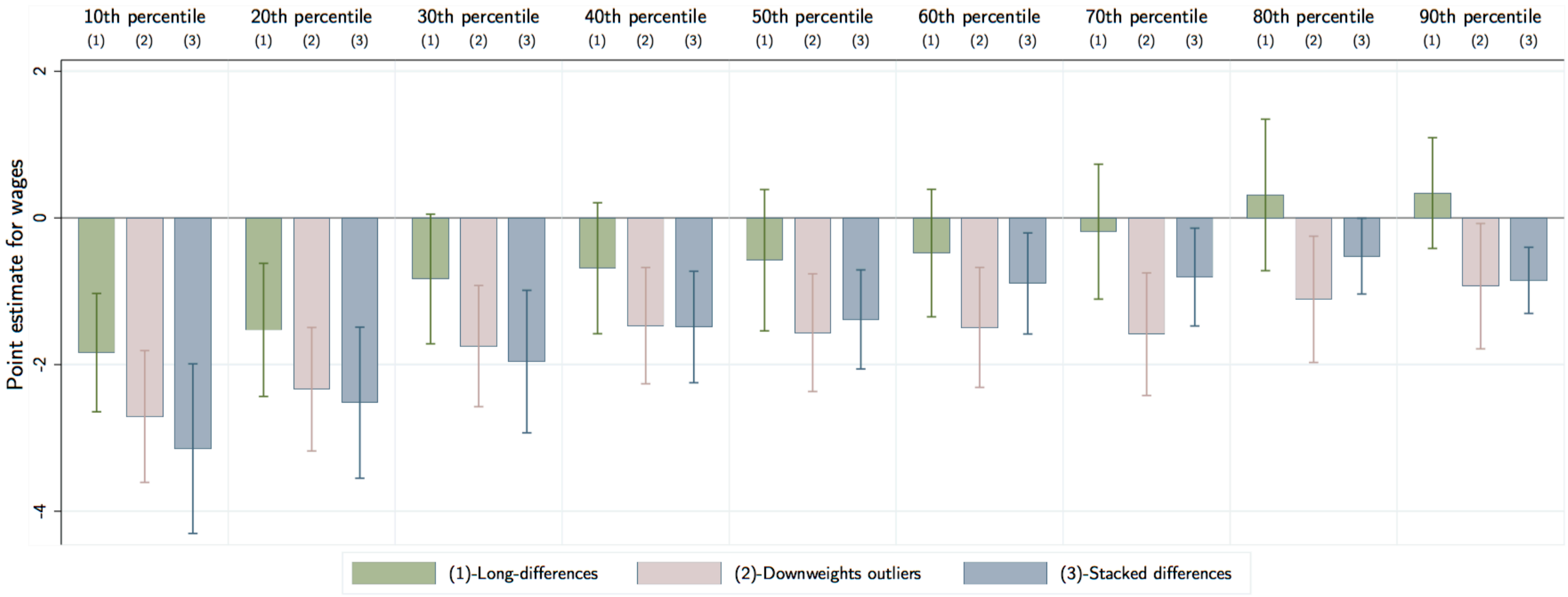

FIGURE 13: RELATIONSHIP BETWEEN THE EXPOSURE TO ROBOTS AND THE WAGE DISTRIBUTION.

Note: The figure shows the estimates of the change in the 10th, 20th, . . . , and 90th wage deciles against the (exogenous) exposure to robots between 1993 and 2007 conditional on the covariates in column 4 of Table 2. The green bars correspond to a long-differences specification similar to column 4 of Table 2; The rose bars correspond to a long-differences specification similar to column 6 of Table 2, in which we downweigh outliers; the blue bars correspond to a stacked-differences specification similar to column 2 of Table 3.

Acemoglu and Restrepo (2017)

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Graetz-Michaels
~250

- Implication for Robots: $t_m^* \simeq 99\%$

with $\epsilon = 0.1$ and $\bar{\tau} = 0.1$ (Guner-Kaygusuz-Ventura)

A TWO-GOOD ECONOMY

- Households

$$U = c - h(n)$$

- New tech firms use final good to produce machines

$$y_m^* = \phi y_f^*$$

- Old tech firms use machines + labor to produce final good

$$y_f = \int g(y_m(\theta), n(\theta); \theta) dF(\theta)$$

$$w(p_m, \{n(\theta)\}; \theta)$$

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our focus

well-known "Stiglitz" effects
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COMPARATIVE STATICS WITH PARAMETRIC RESTRICTIONS

- Rawlsian preferences

$$\Lambda(\theta) = 1 \text{ for all } \theta$$

- Iso-elastic labor supply

$$h(n) = \frac{n^{1+1/\epsilon}}{1+1/\epsilon}$$

- Cobb-Douglas production functions

$$y(r,n;\theta) = \exp(\alpha(\theta)) \cdot (\frac{r}{\beta(\theta)})^{\beta(\theta)} (\frac{n}{1-\beta(\theta)})^{1-\beta(\theta)}$$

- With $\alpha(\theta)$ $\beta(\theta)$ such that Pareto distribution of wages

$$w(p_m;\theta) = (1-\theta)^{-1/\gamma(p_m)}$$

CHEAPER ROBOTS, LESS LUDDISM

- Pareto efficient tax:

$$\frac{t_m^*}{1+t_m^*} = \frac{\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m}\tau^*}{1-\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m}\tau^*}\frac{1-s_m}{s_m}$$

PROP 5.

Pareto efficient tax decreases with robot-makers' productivity.

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Pigou → Lower tax

~~CHEAPER ROBOTS, LESS LUDDISM~~

IMPORTS PROTECTIONISM

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foreign

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CONCLUDING REMARKS

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1. When is technological change welcome?
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     - No rationale for taxing innovation
     - Impact of trade shock only depends on TOT

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More: Other machines? Natural resources? Immigration?

APPENDIX

EXTENSION

PROP 2. No distortion between consumers and New tech

- Intuition…
  - motive for distortion is to manipulate wages…
  - … households do not demand labor and their consumption does not affect wages
- Implication…
  - no trade protection that leads to higher prices for consumers
  - no taxes on Robots for household uses

CORRELATIONS AND BOUNDS

- What goods do we tax more?

COROL 1. Optimal distortion between old and new technology

$$(p^* - p)' \cdot \int (\Lambda(\theta) - F(\theta))(1 - \tau(\theta))x(\theta)(\nabla_p \omega(\theta))dF(\theta) \geq 0$$

- What can we say if we do not know Pareto weights?

COROL 2. Taxes on both old and new technology

$$D_{p_i} y \cdot (tp) \leq \int (\mathbf{1}_{\Theta_i^+}(\theta) - F(\theta))(1 - \tau(\theta))x(\theta)\omega_{p_i}(\theta)d\theta,$$

$$D_{p_i} y \cdot (tp) \geq \int (\mathbf{1}_{\Theta_i^-}(\theta) - F(\theta))(1 - \tau(\theta))x(\theta)\omega_{p_i}(\theta)d\theta$$